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(54) **INTEGRATED GEARBOX LUBE AND CONTROL SYSTEM**

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F16H 47/00 (2006.01)
F16H 61/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F16H 61/0021*** (2013.01); *Y10T 74/19163* (2015.01)

(58) **Field of Classification Search**
USPC 74/730.1, 731.1, 732.1, 733.1
See application file for complete search history.

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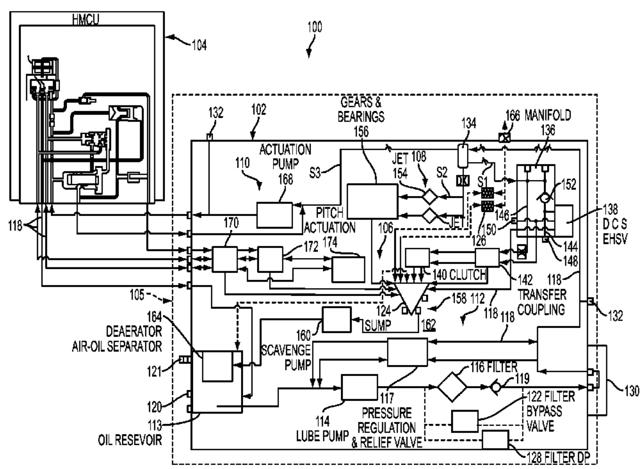
(57) **ABSTRACT**

A gearbox system includes a gearbox having integrated therein a pump system, a plurality of fluid passages and a clutch control system. The pump system is in fluid communication with the clutch control system via the fluid passages to flow at least one pressurized stream. A first pressurized stream controls a first pressure-responsive device included in the clutch control system. The gearbox system further includes a hydro-mechanical control unit (HMCU) in fluid communication with the gearbox to receive a second pressurized stream and to generate at least one actuator control stream. The actuator control stream controls an actuator integrated in the gearbox.

12 Claims, 3 Drawing Sheets



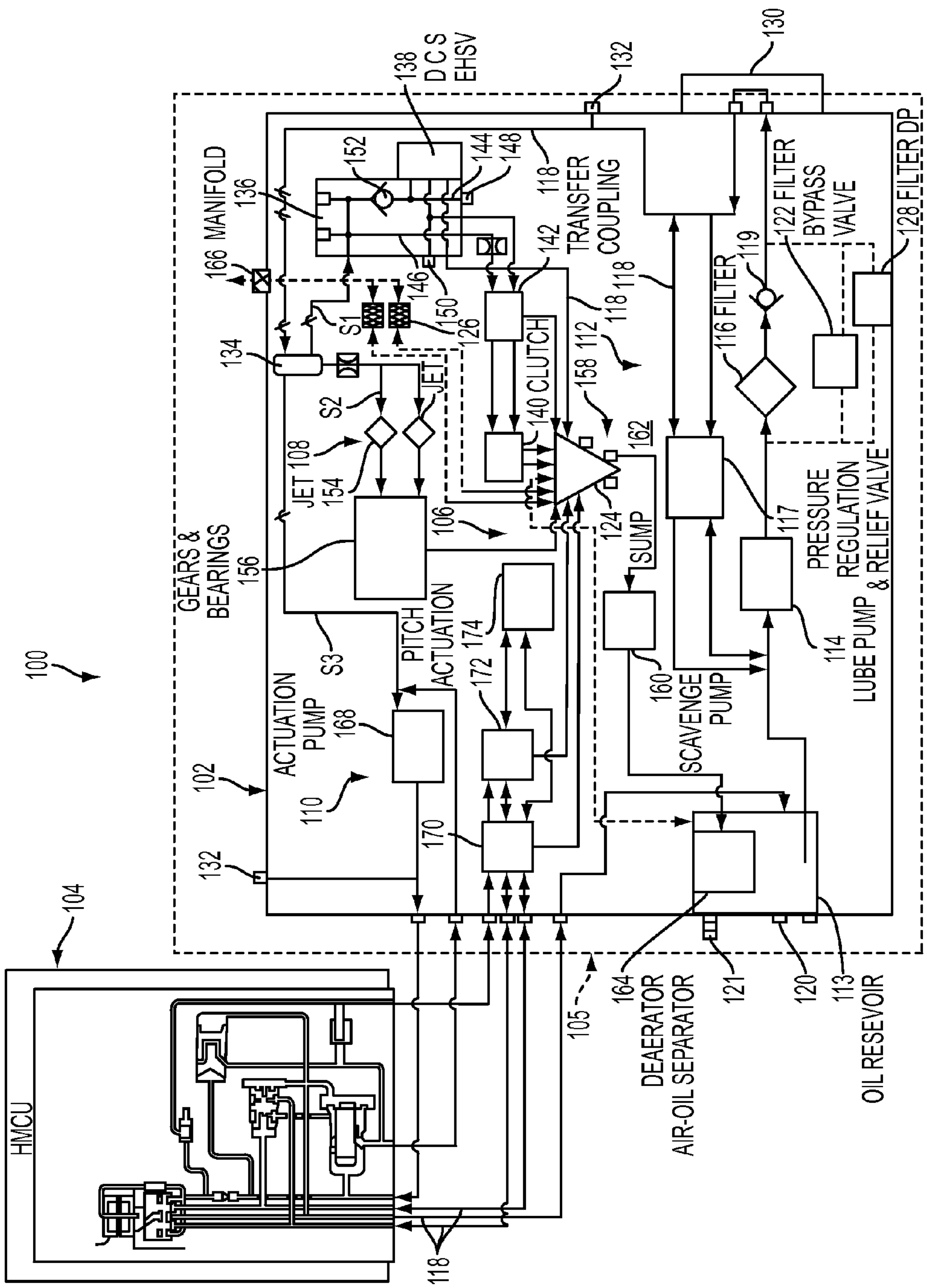

100
102
104
HMCU
105
118
GEARS & BEARINGS
156
JET 108
154
S2
JET
134
S1
S3
166 MANIFOLD
136
152
138
D C S
EHSV
144
148
146
150
126
142
118
TRANSFER COUPLING
140 CLUTCH
158
112
106
162
124
SUMP
ACTUATION PUMP
168
PITCH ACTUATION
172
174
170
110
132
160
SCAVENGE PUMP
117
114
LUBE PUMP
PRESSURE REGULATION & RELIEF VALVE
116 FILTER
119
122 FILTER BYPASS VALVE
128 FILTER DP
130
164
DEAERATOR
AIR-OIL SEPARATOR
121
120
113
OIL RESEVOIR

FIG. 1

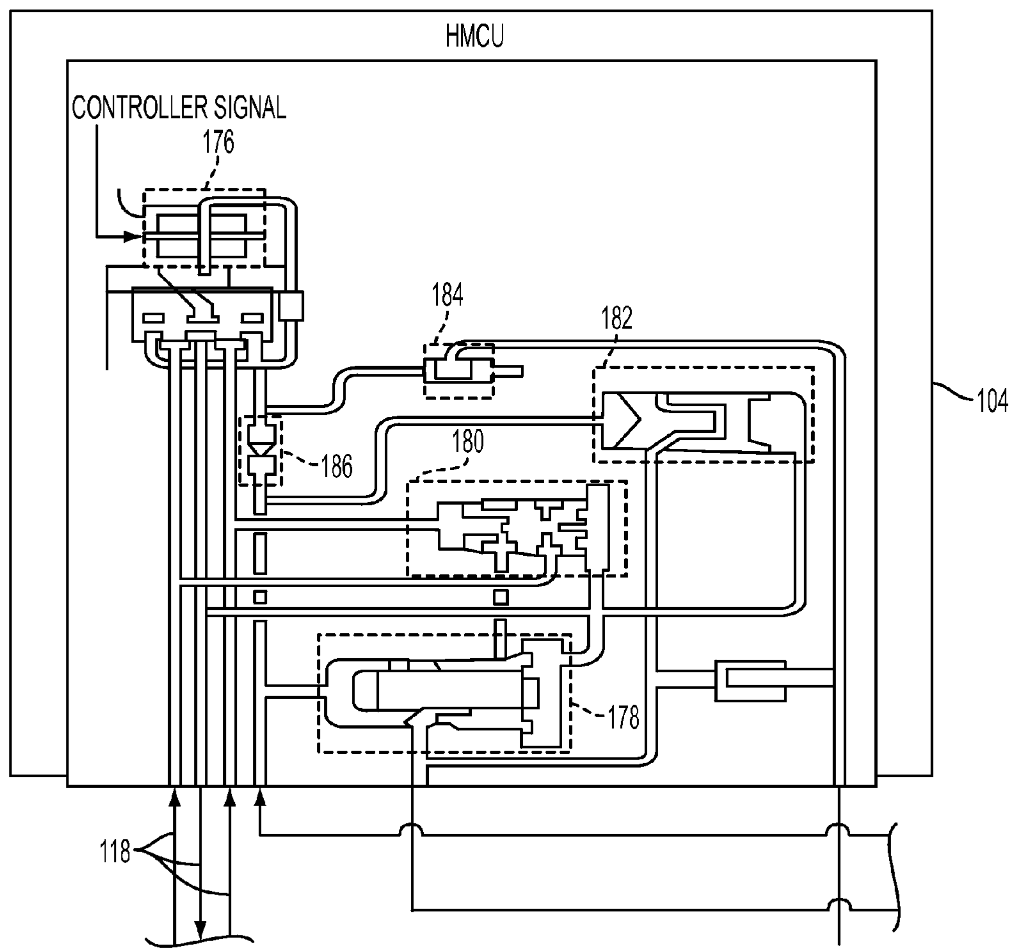


FIG. 2

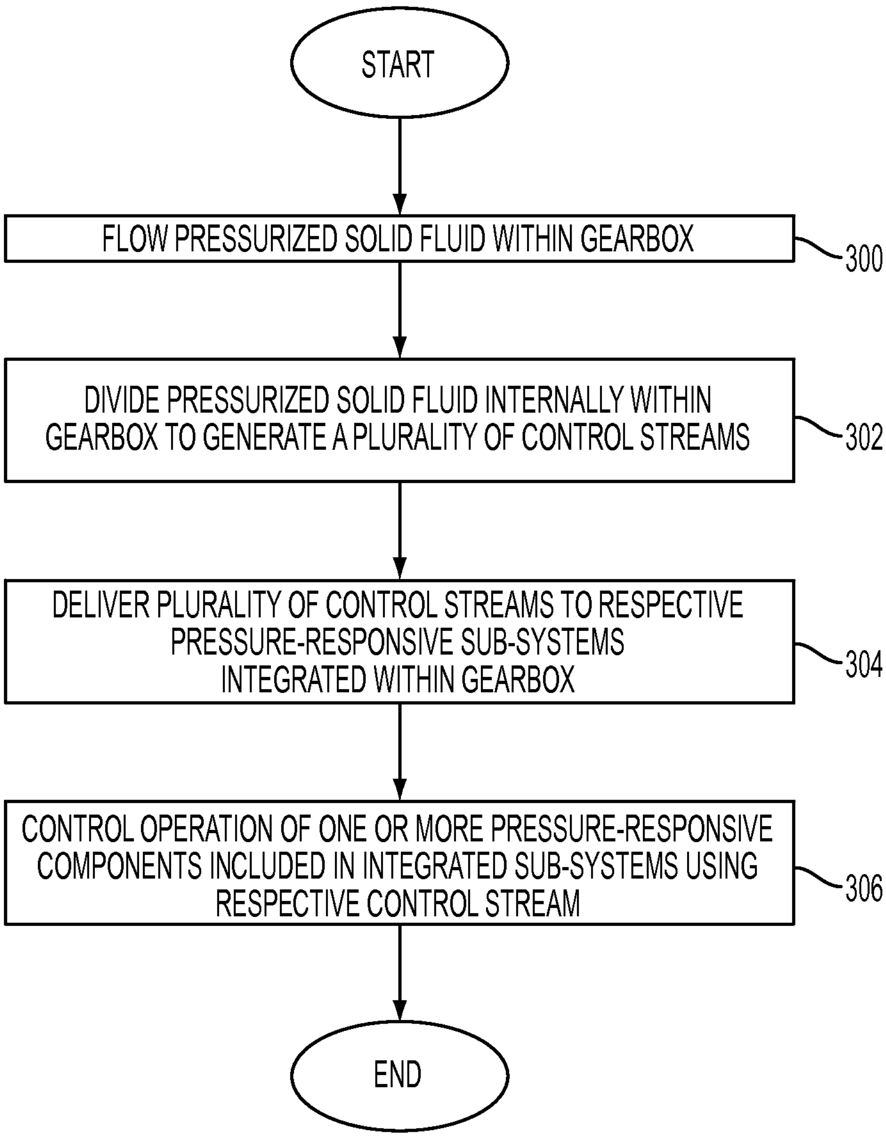

START
FLOW PRESSURIZED SOLID FLUID WITHIN GEARBOX
300
DIVIDE PRESSURIZED SOLID FLUID INTERNALLY WITHIN GEARBOX TO GENERATE A PLURALITY OF CONTROL STREAMS
302
DELIVER PLURALITY OF CONTROL STREAMS TO RESPECTIVE PRESSURE-RESPONSIVE SUB-SYSTEMS INTEGRATED WITHIN GEARBOX
304
CONTROL OPERATION OF ONE OR MORE PRESSURE-RESPONSIVE COMPONENTS INCLUDED IN INTEGRATED SUB-SYSTEMS USING RESPECTIVE CONTROL STREAM
306
END

FIG. 3

INTEGRATED GEARBOX LUBE AND CONTROL SYSTEM

BACKGROUND

A gearbox for an aircraft primarily functions to transmit rotational power through fixed engagements. A common gearbox lube system lubricates and removes heat, where lube oil is typically sourced from an external pumping system and is distributed within the gearbox. However, sometimes multiple functionalities are required that can be difficult to incorporate together and then package into the gearbox. These functionalities can include gearbox lubrication and cooling, a clutch to engage and disengage the gearbox, control of a propeller blade pitch system, and electrical systems with control and sensing capabilities.

Where higher capability and system functionality are necessary, a higher level of complexity and integration effort is required. In addition, a gearbox for an aircraft typically needs to operate at multiple altitudes. These altitudes usually require various aircraft angles and sometimes zero to negative G operation, especially for military aircraft. A typical gearbox is commonly designed with these multiple altitudes in mind. However, implementing multiple systems in a gearbox has been traditionally been challenging.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the various embodiments is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features of the embodiments are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a schematic diagram of a gearbox hydraulic system according to an embodiment of the disclosure;

FIG. **2** is an enlarged view of a hydro-mechanical control unit included in the gearbox system illustrated in FIG. **1**; and

FIG. **3** is a flow diagram illustrating a method of controlling a gearbox hydraulic system according to an embodiment of the disclosure.

DETAILED DESCRIPTION

Referring now to FIG. **1**, a gearbox system **100** is illustrated according to an embodiment. The gearbox system **100** may be utilized by an aircraft; however, the gearbox system **100** is not limited thereto and instead may be utilized in other various systems including, but not limited to, land-based vehicles and naval vessels.

According to an embodiment, the gearbox system **100** includes a gearbox **102** and a hydro-mechanical control unit (HMCU) **104**. The gearbox **102** may transfer rotational power generated by a rotating input shaft (not shown) to rotationally drive a propulsion system, such as a propeller system (not shown) for example. One or more sub-systems may be integrated within the gearbox **102**. In at least one embodiment, the gearbox **102** includes a housing **105** having one or more sub-systems disposed therein. The sub-systems may include, for example, a pressure-actuated hydraulic clutch that selectively engages and/or disengages the gearbox **102** from the input shaft, a hydraulic system to hold and change propeller blade pitch, a gear and bearing system, a three stage pumping system to provide hydraulic control, lubrication and cooling, a reservoir, a deaerator, an accumulator to maintain hydraulic clutch control during zero to negative G attitude operation, a propeller pitch-lock valve to hydraulically lock the propeller

blade angle during zero to negative G attitude operation, and electrical systems to provide hydraulic control and sensing for pressure and temperature.

Referring further to FIG. **1**, the gearbox **102** includes a clutch control system **106**, a lubrication/cooling system **108**, and an actuation system **110**. The gearbox **102** further includes a pump system **112** integrated in the gearbox **102** that draws in fluid contained in a reservoir **113** and delivers it to the clutch system **106**, the lubrication/cooling system **108**, and the actuation system **110**.

More specifically, the main stage pump system **112** comprises of a positive displacement lube pump **114**, a system filter **116**, a pressure regulating valve **117**, and a plurality of fluid passages **118**. The lube pump **114** draws solid fluid in from the reservoir **113** and flows it to the system filter **116** via one or more of fluid passages **118**. In at least one embodiment a plurality of fluid passages **118** is integrated within the gearbox **102**. A check valve **119** may be disposed downstream from the system filter **116** to prevent the solid fluid from flowing backwards during shutdown and/or filter maintenance. The interconnected fluid passages facilitate the interplay of all system elements, and may deliver flow having various pressures such as low-pressure, mid-pressure and high-pressure. For example, low-pressure fluid may have a pressure ranging from about 0 psi to about 300 PSI, mid-pressure fluid may have a pressure ranging from about 300 psi to about 600 psi, and high-pressure fluid may have a pressure of about 600 psi and above. The lube pump **114** is driven in response to rotational power generated by the rotating input shaft. The lube pump **114** generates a pressurized fluid flow of about 300 psi, for example. The reservoir **113** may include a temperature transducer **120** to monitor the fluid temperature therein, and one or more vents **121** to vent the reservoir **113** to atmospheric pressure. Further, the reservoir **113** may include various components to manage and/or service the oil volume therein including, but not limited to, fluid fill and spill ports, a fluid level sight glass, and a fluid drain plug.

The system filter **116** may include a filter bypass valve **122** that bypasses fluid if the system filter **116** becomes blocked. The bypassed fluid may be passed on to the gearbox. The sump **124** may be vented to atmospheric pressure through one or more screened vents **126**. The system filter **116** also includes a filter delta pressure indicator (FDPI) **128**. The FDPI **128** may include a pressure indicator that indicates the pressure across the filter element during various operations including, but not limited to, impending bypass and imminent filter maintenance or replacement.

After passing through the system filter **116**, the fluid exits the gearbox **102** and goes through an external air/oil heat exchanger **130** that regulates, i.e., reduces, the temperature of the fluid. The regulated, i.e., cooler, fluid then re-enters the gearbox **102** and is received by the pressure regulating valve **117**. The pressure regulating valve **117** regulates the flow and pressure of the conditioned fluid at the predetermined pressure. The pressure regulating valve **117** may also function as a relief valve, which bypasses all surplus fluid to the main stage pump inlet. One or more pressure transducers **132** may be in fluid communication with a respective fluid passage **118** to monitor fluid pressure. For example, a pressure transducer **132** is disposed downstream from the pressure regulating valve **117** to monitor the main stage fluid pressure as regulated by the pressure regulating valve **117**. The regulated fluid from the pressure regulating valve **117** is directed to a flow divider **134** that is integral to the core passage system. The flow divider **134** is integrated in the gearbox **102**, and divides the regulated fluid into three control streams (S**1**, S**2**, S**3**). In at least one embodiment, the flow divider **134** is formed integrally from an inner surface of the gearbox **102**. The three control streams (S**1**, S**2**, S**3**) are directed to the clutch control system **106**, the lubrication/cooling system **108**, and the actuation system **110**, respectively, to control various operations thereof as described in greater detail below. Accordingly, integrating the flow divider **134** in the gearbox **102** may achieve one or more control streams that conveniently allow for integrating one or more sub-systems, such as an actuation system, a pump system, etc., within the gearbox **102**.

The clutch control system **106** comprises a manifold **136** and an electro-hydraulic servo valve (EHSV) **138**. In at least one embodiment, the clutch control system is integrated in the gearbox **102**. The manifold **136** receives the first stream (S**1**) from the flow divider **134**, and generates cooling, lubrication, actuation flow, and pressure that are selectively output to a hydraulic clutch **140**. Accordingly, the clutch **140** may be selectively engaged and disengaged as described further below. When the clutch **140** is engaged, the output shaft of the gearbox **102** becomes synchronized with the constantly rotating input shaft. When the clutch **140** is disengaged, the gearbox **102** is disconnected from the rotating shaft. The gearbox **102** may further include a clutch transfer coupling device **142** that allows external fluid to pass into and through the rotating input shaft.

The EHSV **138** is in electrical communication with the manifold **136** and a remotely located clutch control module (not shown). The clutch control module may output a control signal that indicates a desire to engage/disengage the clutch **140**. The EHSV **138** receives the control signal from the clutch control module, and instructs the manifold **136** to engage/disengage the clutch **140**. In the case where the clutch **140** is to be engaged, the EHSV **138** converts a clutch control signal and provides hydraulic pressure and flow to the manifold **136**. Based on the control signal, the manifold **136** delivers the actuation flow, and pressure to engage and synchronize the clutch **140**. If the clutch **140** is to be disengaged, the EHSV **136** terminates the clutch signal, which causes the manifold **136** to inhibit delivery of the actuation flow, and pressure. As the actuation flow and pressure decreases, the clutch **140** becomes disengaged. The coolant and lubrication flows are fed continuously regardless of the clutch status.

The clutch control system **106** may also include one or more sensors, which provide feedback information to the clutch control module. Based on the feedback information, the clutch control module may output additional control signals to the EHSV **138**. It is appreciated that although the embodiment illustrated in FIG. **1** utilizes the manifold **136** and EHSV **138** to control operation of a clutch control system, the clutch control system may be replaced with another type of actuation system to be controlled using the manifold **136** and the EHSV **138**.

In a case where the gearbox **102** is implemented in an aircraft system, the manifold **136** may further include two output ports **144**, **146**, that attach to an accumulator **148** and the pressure transducer **150**, respectively, which monitor the fluid pressure. During zero to negative G attitude operation, the accumulator **148** discharges to continue hydraulic clutch operation. A check valve **152** may be provided in manifold **136** to prevent fluid from returning into the distribution system, and excessively reducing the pressure used for clutch actuation within the manifold **136**.

The lubrication/cooling system **108** receives the second stream (S**2**) output from the flow divider **134**. In at least one embodiment, the lubrication/cooling system **108** is integrated in the gearbox **102**. The lubrication/cooling system **108** comprises one or more coolant components **154** including, but not limited to, jets and orifices that lubricate and cool one or more gearing/bearing systems **156** operating in the gearbox **102**. For example, one gear/bearing system **156** may be associated with the clutch **140**. Accordingly, the lubrication/cooling system **108** may deliver cooled lubricating fluid to the gear/bearing system **156** to prevent overheating.

The gearbox **102** may further include a debris filter system **158**. The debris filter system **158** may include a positive displacement scavenge pump **160**, a screened chip detector **162**, and a deaerator **164**. Leakage and drainage fluid from various portions of the gearbox system **100**, such as the HMCU **104**, clutch control system **106**, manifold **136**, gear/bearing systems **156**, etc., may be collected in the sump **124**. The positive displacement scavenge pump **160** may be driven by the rotating input shaft, and may flow fluid mixed with air from the sump **124** through the screened chip detector **162**, which collects and monitors debris in the air/fluid mixture. The air/fluid mixture is then sent through the deaerator **164** that separates the air from the fluid. The separated air is directed back to the sump **124** and the solid fluid is directed into the reservoir **113** such that processes performed by the pumping system **112** may continue.

The actuation system **110** may be utilized to control and/or move various types of pressure-responsive devices. According to an embodiment illustrated in FIG. **1**, the actuation system **110** is integrated in the gearbox **102**, and may be utilized to control a pitch of a moveable propeller blade unit (not shown). Although one embodiment utilizes the actuation system **110** to control a pitch of a propeller blade unit, the actuation system is not limited thereto. The actuation system **110** further includes a positive displacement actuation pump **168**, an actuator transfer coupling device **170**, a propeller pitch-lock valve (PPLV) **172** and an actuator, e.g., a pitch actuator **174**. Accordingly, the actuation system **110** works together with the HMCU **104** to control the pitch actuator **174** and adjust the pitch of the propeller blade unit. For example, the HMCU **104** receives an increased fluid pressure output from the actuation pump **168**, which is driven by the rotating input shaft, and generates an actuator control stream that provides fluid pressure for controlling a movement of the pitch actuator **174**. The actuation pump **168** may increase the fluid pressure of the third stream (S**3**), for example, from about 300 psi to about 600 psi or greater. As previously mentioned, although the actuator control stream is described above to control a pitch actuator **174**, the actuator control stream may be utilized to control other types of actuators that control other types of mechanical components.

Referring now to FIG. **2**, the HMCU **104** described above is illustrated in greater detail. The HMCU **104** may include a second electro-hydraulic servo valve (EHSV) **176**, a pressure regulating valve **178**, and a selector valve **180**, which all work to provide flow and pressure to the actuation system **110** to control the pitch of propeller blade unit.

The second EHSV **176** may operate similar to the first EHSV **138** discussed above. More specifically, the second EHSV **176** may receive an electronic control signal from a main actuator control module (not shown) located remotely from the HMCU **104**. The electronic control signal generated by the actuator control module may indicate a desire to adjust a mechanical component, such as the propeller blade unit, controlled by an actuator, such as the pitch actuator **174**. In response to the control signal, the EHSV may control one or more valves, e.g., the pressure regulating value **178**, the selector valve **180**, etc., to output a fluid control signal, which controls one or more actuation systems **110**. The actuation system **110** may also include one or more sensors, which provide feedback information to the main actuator control module. Based on the feedback information, the actuator control module may output additional electronic control signals to the EHSV **176**.

The HMCU **104** may also include a pressure regulating valve **182**. The pressure regulating valve **182** may also serve as a bypass, which returns surplus fluid to the reservoir **113**. The actuator transfer coupling device **170** allows external fluid to pass into and through the propeller blade positioning actuator. During normal operation when the full supply pressure is present, the PPLV **172** allows actuation fluid to pass through to control the pitch angle of the propeller blade unit. However, when supply pressure is interrupted, as during zero to negative G altitude operation, the PPLV **172** hydraulically locks the propeller blade unit to hold at the last commanded angle set prior to experiencing the interruption.

In at least one embodiment, the HMCU **104** may be set to an atmospheric pressure through the reservoir, where leakage and actuation return flow is delivered. Further, the HMCU **104** may include two ground actuation check connections **184** and one or more check valves **186**, which may be connected to an external control system (not shown) that may service the gearbox system **100**. The check valves **186** may also be in fluid communication with the sump **124** to provide a separate drain path thereto.

Referring now to FIG. **3**, a flow diagram illustrates a method of controlling a gearbox hydraulic system according to an embodiment of the disclosure. At operation **300**, a pressurized solid fluid is flowed within the gearbox, i.e., internally. As discussed above, the pressurized solid may be drawn from a reservoir and flowed internally throughout the gearbox using a main stage pump system. At operation **302**, the pressurized solid fluid is divided into a plurality of control streams. In at least one embodiment discussed above, a flow divider is integrated inside the gearbox and divides the main pressurized solid flow delivered by the pump system into a plurality of control streams. Each control streams is delivered to a respective pressure-responsive sub-systems integrated within the gearbox at operation **304**. For example, a first control stream may be output from the flow divider to a clutch control system, while a second control stream may be simultaneously output from the flow divider to an actuation system. At operation **306**, one or more pressure-responsive components included in the pressure-responsive sub-systems are controlled according to the respective control stream, and the method ends. For example, the first control stream may control a hydraulic clutch included in the clutch control system, while the second control stream may control the operation of a hydraulic actuator included in the actuation system. Accordingly, a gearbox hydraulic system may be provided, which includes multiple hydraulic sub-systems integrated within the gearbox.

While various embodiments have been described in detail, it should be readily understood that the inventive concept is not limited to such disclosed embodiments. Rather, the embodiments may be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the inventive concept. Additionally, while the various embodiments have been described, it is to be understood that features may be included only some of the described embodiments. Accordingly, the embodiments are not to be seen as limited by the foregoing description.

What is claimed is:

1. A gearbox system, comprising:

a gearbox having integrated therein a pump system, a plurality of fluid passages and a clutch control system, the pump system in fluid communication with the clutch control system via the fluid passages such that the pump system flows at least one pressurized stream to control a first pressure-responsive device included in the clutch control system, and a flow divider integrated therein to receive the at least one pressurized stream and to divide the at least one pressurized stream into a plurality of control streams wherein the plurality of control streams includes a first control stream output to the clutch control system and a second control stream output to a hydro-mechanical control unit (HMCU); and

wherein the hydro-mechanical control unit (HMCU) is in fluid communication with the gearbox to receive the at least one pressurized stream and to generate at least one actuator control stream.

2. The gearbox system of claim **1**, wherein the clutch control system comprises:

a hydraulic clutch selectively operable in an engaged position and a disengaged position based on fluid pressure;

a manifold that selectively outputs the first control stream to the hydraulic clutch; and

an electro-hydraulic servo valve (EHSV) that receives an electrical control signal and that controls the manifold to output the first control stream based on the electrical control signal, the hydraulic clutch induced to the engaged position in response to receiving the first control stream and induced to the disengaged position when the lacking the first control stream.

3. The gearbox system of claim **2**, wherein the gearbox further comprises an actuation system integrated therein, the actuation system being in fluid communication with the HMCU to receive the at least one actuator control stream.

4. The gearbox system of claim **3**, wherein the actuation system includes a second pressure-responsive device that operates based on fluid pressure from the at least one actuator control stream.

5. The gearbox system of claim **4**, wherein the second pressure-responsive device is a pitch actuator to control movement of a propeller blade unit.

6. The gearbox system of claim **4**, wherein the HMCU comprises:

a servo valve that selectively outputs the at least one actuator control stream in response to an actuator control signal; and

a second EHSV that receives an electrical controller signal and that generates the actuator control signal to control output of the at least one actuator control stream.

7. The gearbox system of claim **6**, wherein the gearbox includes a lubrication and cooling system integrated therein, the lubrication and cooling system configured to cool and lubricate a gear and bearing system of the gearbox based on a third control stream generated by the flow divider.

8. A gearbox, comprising:

a housing surrounding a gear system of the gearbox;

a first fluid pressure-responsive system disposed within the housing;

a second fluid pressure-responsive system disposed within the housing;

a pump system disposed within the housing, the pump system flowing a solid pressurized fluid through a plurality of fluid passages disposed within the housing;

wherein the gearbox comprises a flow divider disposed within the housing to divide the solid pressurized fluid into a first control stream output to the first fluid pressure-responsive system and a second control stream output to the second fluid pressure-responsive system; and

wherein the first fluid pressure-responsive system is a clutch control system comprising:

a hydraulic clutch that is selectively operable in an engaged position and a disengaged position based on fluid pressure;

a manifold that selectively outputs the first control stream to the hydraulic clutch; and

an electro-hydraulic servo valve (EHSV) that receives an electrical control signal and that controls the manifold to output the first control stream based on the electrical control signal, the hydraulic clutch induced to the engaged position in response to receiving the first control stream and induced to the disengaged position when the lacking the first control stream.

9. The gearbox of claim **8**, wherein the second pressure-response system is an actuation system that controls operation of a hydraulic actuator based on the second control stream.

10. The gearbox of claim **9**, further comprising a lubrication and cooling system disposed within the housing, the lubrication and cooling system configured to cool and lubricate the gear system based on a third control stream generated by the flow divider.

11. The gearbox of claim **10**, wherein the pump system comprises:

a reservoir to contain solid fluid; and

a positive displacement pump that is driven by rotational power generated by rotation of an input shaft, the positive displacement pump in fluid communication with the reservoir to output the pressurized solid fluid to the flow divider.

12. A pressure-system integrated gearbox, comprising:

a plurality of pressure-responsive systems integrated in the gearbox wherein the plurality of pressure responsive systems includes a clutch control system, a lubrication system, and an actuation system;

a pump system integrated in the gearbox, the pump system configured to flow a solid pressurized fluid through a plurality of fluid passages integrated in the gearbox; and

a flow divider integrated in the gearbox and disposed in fluid communication with the pump system, the flow divider configured to divide the solid pressurized fluid into a plurality of controls streams, each control stream being output to a respective pressure-responsive system among the plurality of pressure-responsive systems, wherein the plurality of a control streams include a first control stream output to the clutch control system to control a hydraulic clutch, a second control stream different from the first control stream that is output to the lubrication system to lubricate a gear system, and a third control stream different from the first and second control streams that is output to the actuation system to control a hydraulic actuator.

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